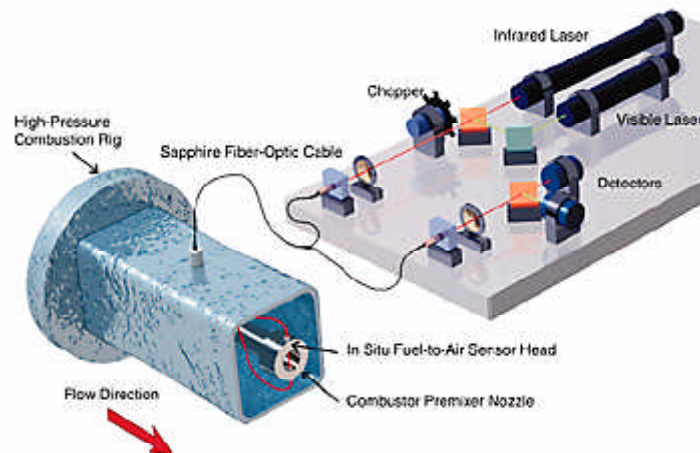


Time-Resolved Optical Measurements of Fuel-Air Mixedness in *Windowless* High Speed Research Combustors

Fuel distribution measurements in gas turbine combustors are needed from both pollution and fuel-efficiency standpoints. In addition to providing valuable data for performance testing and engine development, measurements of fuel distributions uniquely complement predictive numerical simulations. Although equally important as spatial distribution, the temporal distribution of the fuel is an often overlooked aspect of combustor design and development. This is due partly to the difficulties in applying time-resolved diagnostic techniques to the high-pressure, high-temperature environments inside gas turbine engines. Time-resolved measurements of the fuel-to-air ratio (F/A) can give researchers critical insights into combustor dynamics and acoustics.

Beginning in early 1998, a *windowless* technique that uses fiber-optic, line-of-sight, infrared laser light absorption to measure the time-resolved fluctuations of the F/A (refs. 1 and 2) will be used within the premixer section of a lean-premixed, prevaporized (LPP) combustor in NASA Lewis Research Center's CE-5 facility. The fiber-optic F/A sensor will permit optical access while eliminating the need for film-cooled windows, which perturb the flow. More importantly, the real-time data from the fiber-optic F/A sensor will provide unique information for the active feedback control of combustor dynamics. This will be a prototype for an airborne sensor control system.



Fiber-optic F/A sensor apparatus. The optics are mounted on a 4- by 2-ft optical breadboard. An electron beam brazing technique developed at Lewis was used to hermetically seal the sapphire fiber inside a small stainless steel tube. The chopper is used for calibration purposes only; without the chopper, the bandwidth of the instrument is 1 MHz.

The illustration shows a schematic of the fiber-optic F/A sensor apparatus under development for NASA's High Speed Research (HSR) program. Infrared and visible light

(3.39 μm and 633 nm) from two helium/neon lasers are combined using a beam splitter. The light then enters a sapphire optical fiber that guides it to the inside of the high-pressure combustor rig. (Sapphire transmits infrared light and can withstand temperatures up to 1800 °C.) A small parabolic mirror collimates and directs the light across the premixer nozzle, where fuel vapor will attenuate only the infrared wavelength but fuel droplets or particulates will attenuate both wavelengths. The ratio of the transmitted infrared light to the visible light intensities provides time-resolved and quantitative measurements of the fuel vapor and droplet number densities. After traversing the premixer nozzle, the light is then refocused into a return fiber, whereupon it is spectrally separated and directed to both infrared and visible light detectors. The signals from the detectors are processed in real time for online control. Future versions will use compact diode lasers, providing a more robust instrument for flight use.

In addition, the AST program will be using a high-speed fuel vapor sensor based on this technique to detect the presence of fuel leaks in the new Advanced Subsonic Combustor Rig (ASCR) windowed sector rig. The sensor will initiate an emergency shutdown if enough fuel vapor accumulates to create an explosion hazard (1300 °F and 900 psia). Conventional fuel leak detection, which requires an extractive sample line connected to a remote hydrocarbon gas analyzer, would have a response time on the order of tens of seconds. The fiber-optic fuel-air sensor, which responds in real time, will serve as a mission critical component of the ASCR test rig.

In the Fast Quiet Engine Program (High Speed Research), the fiber-optic F/A sensor will provide time-resolved F/A information in conjunction with acoustic instability information from microphones for the active-feedback dynamics control of future gas turbine combustors.

References

1. Mongia, R., et al.: Proceedings from the 26th International Symposium on Combustion. The Combustion Institute, Pittsburgh, PA, 1996.
2. Dibble, R.W.; Mongia, R.; and Nguyen, Q.V.: U.S. Patent Application Serial No. 696,296, 1997.

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Programs/Projects: HSR, AST, ASCR, FQE, other applications requiring remote detection of fuel or hydrocarbon vapor